

Semantic Suppression in Figure-Ground Perception and
Binocular Rivalry

By

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A Thesis Submitted to The Honors College
In Partial Fulfillment of the Bachelors degree

With Honors in
Psychology

THE UNIVERSITY OF ARIZONA

May 2010

Approved by:

A handwritten signature in black ink, appearing to read "Mary A. Peterson", with a long horizontal line extending to the right.

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Abstract

Figure-ground segregation occurs when one of two regions sharing a border is perceived as a shaped entity (a figure) and the other is perceived as a shapeless background to the figure. The mechanism of figure-ground perception is inhibitory competition. Peterson & Skow (2008) showed that a familiar configuration that loses the competition for figural status is not perceived consciously and is suppressed, at least at the level of categorical shape. A remaining question is whether the semantics of the familiar configuration are also accessed and suppressed. The present study investigates this question through binocular rivalry. Binocular rivalry occurs when separate images are simultaneously presented to the left and right eyes. Typically one dominates at any given moment, and awareness alternates back and forth between these two images. The image that is not perceived is suppressed (Wheatstone, 1838). The present experiments investigated how the suppression in figure-ground perception and the suppression in binocular rivalry interact. In one eye, subjects viewed a silhouette that initially dominated because a dynamic, colorful pattern was presented within the confines of the figure. In the other eye, participants viewed a word string either a word that named a familiar configuration or a non-word; the letter string was initially suppressed. Experiment 1 explored whether the time required for the letter string to reach awareness between a silhouette that had a hidden, familiar configuration on the ground side or a silhouette with a novel configuration on the ground. Experiment 2 observed the time required to make a lexical decision once the letter string arrived to awareness. Both experiments failed to yield evidence for an interaction between figure-ground and binocular rivalry suppression. This suggests that during binocular rivalry, a shape suppressed by figure-ground competition fails to interact with a word corresponding to the suppressed shape.

Semantic Suppression in Figure-Ground Perception and Binocular Rivalry

When two regions in the visual field share a border, one often appears to have a definite shape and is seen as “figure,” while the other appears shapeless and continues behind the figure as its background “ground”. Both high- and low-level properties affect what is perceived as figure or ground and determine the outcome of competition between objects that might be seen in either the figure or ground region (although the competition occurs outside of awareness; Peterson & Skow, 2008).

Peterson and Lampignano (2003; Peterson & Enns, 2005) showed that competition for figural status takes time. Peterson and Skow (2008) demonstrated that the shape that loses the competition is suppressed. They presented small, closed, novel silhouettes as figures. Half of these novel figures had portions of familiar shapes suggested *but not perceived* in the background; the other half did not (experimental and control silhouettes, respectively; see Figure 1). Peterson and Skow showed these silhouettes briefly before line drawings and asked subjects to categorize the *line drawings* as portraying a novel object or an object that exists in the real world. (Subjects made no response to the silhouettes.) They found that it took subjects longer to correctly categorize line drawings of objects from the same basic level category as the configuration hidden in the background of the preceding silhouette than a line drawing of an object from a different basic level category. This finding suggested the familiar configuration on the outside of silhouette was processed to the level of categorical shape, and was inhibited when it lost the competition for figural status (and was determined to be ground).

What remains to be determined is whether the hidden shape in the ground was processed at an even higher semantic level, and whether the competition-induced inhibition extends to the

semantic level as well as the categorical shape level. We used binocular rivalry to examine this question.

In binocular rivalry, conflicting monocular images are presented to each eye. Because the two images are too different to be fused into a single percept, they compete for dominance. The dominant image is perceived consciously while the non-dominant image is suppressed (Wheatstone, 1838). Dominance in binocular rivalry is affected by stimulus factors, (i.e., high contrast images are likely to dominate low contrast images, and flashing moving images are more likely to dominate stationary, unchanging images). Nevertheless, the non-dominant image tends to emerge from suppression, and when it does, the percept reverses. Competition between rivalrous percepts is believed to take place at both high and low visual areas in the brain (Tong, Nakayama, Vaughan, & Kanwisher 1998). At lower levels, competition occurs between monocular neurons while, at higher levels, competition occurs between binocular neurons which integrate information from both eyes. At a still higher level, competition occurs between patterns that might be processed to the level of semantics and perceptual recognition.

Throughout the history of binocular rivalry research, the question of whether or not words are processed to the semantic level while under suppression has been under great scrutiny. Previous experiments have suggested that suppression neutralizes semantic information, thereby eliminating word recognition and semantic priming. (Zimba & Blake 1983). Conversely, recent experiments showed that an upright face emerges from suppression faster than an inverted face, and a suppressed word in a familiar language emerges from suppression faster than one in an unknown language (Jiang, Costello, & He 2007). This raises the possibility that the familiarity of an item persists even through suppression. Of course, familiarity assessments do not require access to semantics. Nevertheless, Jiang, et al.s' binocular rivalry paradigm suggested a way to

investigate if the semantics of non-dominant words are accessed in binocular rivalry while simultaneously testing if the semantics of an object, (suggested but not seen) on the outside of a figure, are inhibited as well.

By combining the methods used in binocular rivalry and figure-ground segregation, we presented a silhouette with either a novel or suggested shape in the ground as the dominant percept and a letter string that either named that shape or did not, as the non-dominant percept. In Experiment 1 we investigated how long it took for the letter strings to arrive in awareness from suppression and in Experiment 2 we measure how long participants needed to make a word/non-word decision once the letter string arrived in awareness. We predicted that the arrival of the word in awareness would be slowed when it named the suppressed shape on the ground side of the dominant silhouette. We also predicted that lexical decisions would be slowed in the same condition. Such results would indicate that the shape on the ground side of the silhouette's edge has been processed to the level of semantics. We failed to find support for our hypothesis.

Experiment 1

In Experiment 1, we used continuous flash suppression to ensure that a silhouette figure shown in one eye would initially be the dominant percept, and a letter string shown in the other eye would be suppressed. Continuous flash suppression occurs in binocular rivalry when a percept in one eye is suppressed due to a dynamic, high contrast, colorful stream presented in the other eye. We tested how long it took for the letter string in the non-dominant eye to emerge from suppression and reach awareness by recording subjects' response times (RTs) to indicate whether the letter string was located above or below the middle of silhouette.

There were two types of silhouettes: one with a novel figure and a familiar configuration suggested, but not perceived, on the ground side of the silhouette border (experimental

silhouette), and another with a novel figure and novel ground that suggested no familiar configuration (control silhouette). There were also two types of letter strings: half named the familiar configuration in the experimental silhouettes (word), and another half were not English words, (non-words). In the word condition, words that suggested the suggested familiar configuration on the ground side of the silhouette were presented to one eye (manipulated to be the non-dominant eye) and either an experimental or control silhouette was presented to the other eye (manipulated to be the dominant eye). In the non-word condition, a non-word was presented to one eye (non-dominant) and an experimental or control silhouette was presented to the other (dominant) eye. A diagram of these conditions can be seen in Figure 1.

The difference in RTs to report the emergence of the word when it was paired with an experimental versus a control silhouette was of primary interest. We reasoned that if the semantics associated with the object on the outside of the dominant figure were to interact with the semantics of the suppressed word in the non-dominant eye, then the RT's for words associated with the object on the silhouette's ground should be longer. In other words, RT's should be longer for words paired with experimental than control silhouettes. Such a finding would indicate that the semantic content associated with the shape suggested on the outside of a figure, but not perceived is accessed while perceiving the silhouette and is then suppressed. Peterson and Skow (2008) demonstrated suppression at the level of categorical shape structure, but their results did not speak to whether or not access and or suppression occurred at the semantic level. Alternatively, if the word rises to awareness faster with the experimental silhouette than the control, that would suggest that the semantics of the unperceived shape in the outside of the experimental silhouette had been processed, but not suppressed.

The non-word condition allows us to see if semantic content affects the letter strings arrival to awareness. Although there is some evidence suggesting the familiarity, (either Hebrew words or Chinese characters) of a binocularly suppressed word affects the time it takes to reach awareness, (Jiang et. al. 2007) it is not certain how familiarity affects English words versus non-words. In this study we will address whether semantic content affects a letter string arrival into awareness. Since there is semantic content associated with a word compared to a non-word, it is assumed that this will in turn enable the word to arrive quicker into awareness. If there exists a difference between words and non-words arrival to awareness, we expect to see a difference between the word condition compared to the non-word condition.

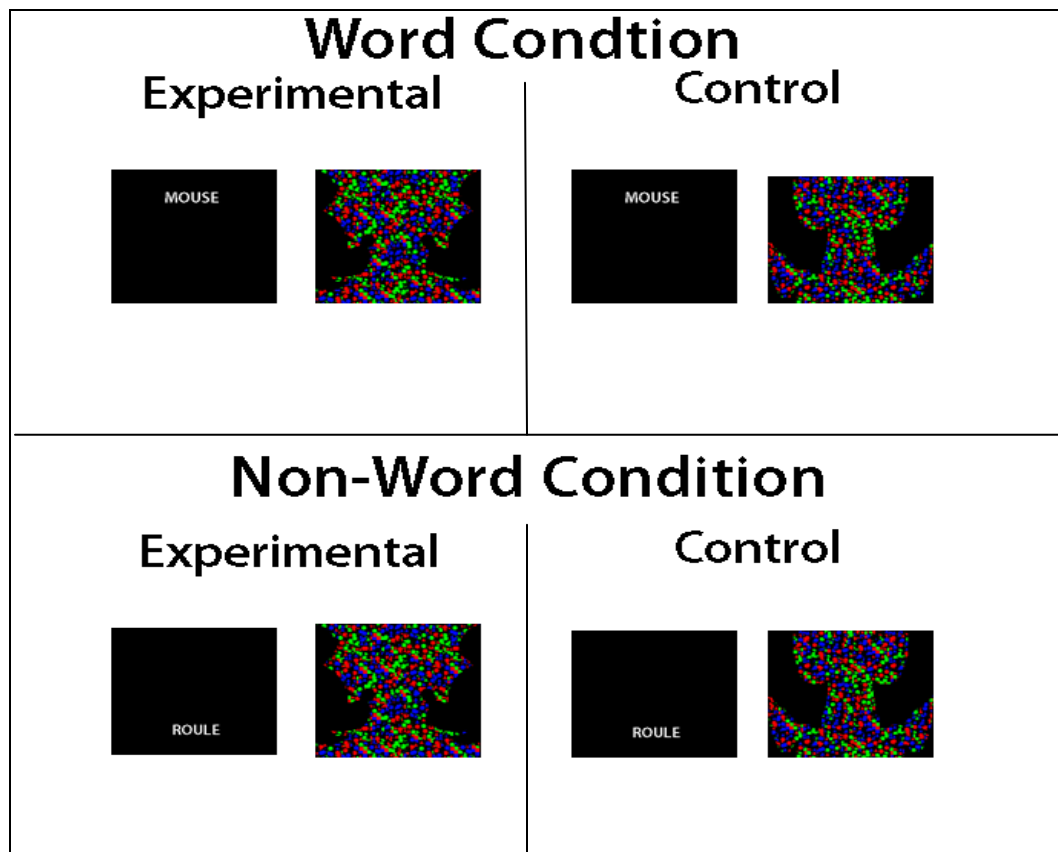


Figure 1. The top panel shows sample trials with experimental and control silhouettes in the word condition and the bottom panel shows them in the non-word condition. Notice how the black part on the ground side of the experimental silhouette sketches a portion of Mickey Mouse. The silhouettes were designed so that the familiar configuration the outside of the experimental figures was not perceived and was putatively inhibited. In the word condition the word “mouse” names the inhibited object on the outside of the experimental silhouette.

Methods

Participants. Participants were 43 undergraduate students (23 females) from the University of Arizona subject pool. All participants had normal or corrected-to-normal visual acuity. Data from 9 participants were not analyzed because their error rate exceeded the criterion (>15%) or they saw the hidden figures in the background (2 participants).

Stimuli and Apparatus. The displays were centered on a computer screen 40 cm from a chin rest positioned so that each subject’s view was level with the center of the displays. The images were displayed side by side on the computer screen and were merged together using a haplscope positioned over the chin rest. This remained in the same position throughout the entire experiment. The stimuli were presented on a 16-in View Sonic monitor (1024x768). The subjects responded to the displays using a custom button box positioned horizontally in line with the computer and the chin rest. Subjects also used a foot pedal to proceed through the instructions and initiate each trial. The software used to present the displays was DMDX.

The stimuli for this experiment were symmetric, enclosed, black outline silhouettes on a black background with a mean visual angle of $10.7^\circ \times 10.7^\circ$ in height (H) and width (W), respectively with 72 pixels per inch. On the inside of the silhouette was a high contrast, colored, dynamic pattern. There were two different display types. The vertical edges of control silhouettes

(N=26) were novel configurations along the ground side and the figure side as shown in Figure 1 rightmost images. These novel shapes do not resemble objects in the real world. The vertical edges of the experimental silhouettes (N=26) had a familiar configuration suggesting a portion of a known shape on the black ground side of the silhouette borders, (mouse in Figure 1) and a novel configuration along the inside of the silhouette. The letter strings displayed in this experiment were white, Myriad Pro, and semi bold in 24point font. The words presented (N=26) represented the objects on the outside of the silhouette. The non-words presented (N=26) were composed of the real words, except that the consonants were replaced enabling them to be non-words. In other words, all the consonants in a word were replaced by consonants that had been in other words in the set. Thus, the non-words were pseudo-words in that they had the same structure as real words.

Two groups of subjects participated in this experiment. Each group saw half the This experiment was equally split into 2 test in order to limit the number of experimental silhouettes (N=13 each). All subjects saw the same 26 words, 13 paired with experimental silhouettes and 13 paired with control silhouettes, but the pairing switched for the two groups, (this way all words appeared equally often in the experimental and the control conditions). The word sets were balanced for, number of letters, frequency of use according to the British National Corpus®, the location they appeared within the figure of the silhouette (top and bottom); and for number of living and non-living entities named. The silhouettes and letter strings were also balanced so they appeared an equal number of times in the left and right eye.

A fixation cross ($0.8^{\circ} \times 0.8^{\circ}$) was presented in each eye before each trial directly in the center of the silhouette. This served as a reference that participants could use to make a top or bottom decision on the word.

Procedure. First, the haploscope was adjusted for each participant so that when a fixation cross was presented to each eye, they fused together giving the illusion of being in the center of the computer screen. Next, instructions were given verbally. Participants were informed to look directly at the cross and to press the foot pedal when they were ready to begin. After pressing the foot pedal, a flashing silhouette appeared in one eye and the word appeared in the other for 1 second, (refer to Figure 2). The participants reported whether the letter string was located above or below the previously seen fixation cross when it entered awareness. The display was presented for 1 second and participants had 2 seconds to respond, at which point the display automatically proceeded to the next trial. They could advance to the next trial at their own pace by pressing the foot pedal.

There were three key features to our approach. First, the word/non-word was competing against a noise pattern present in the figure of the silhouette and would enter awareness on either the top or bottom of the figure. Second, in each trial, as soon as the participant detected the location of the word/non-word or any part of it, the trial ended. This allowed for only the suppression duration to be recorded, as well as keeping the participant restricted in seeing the experimental silhouettes to a minimum. Third, the dynamic noise pattern was displayed at full contrast, whereas the word/non-word was steadily increased to full contrast in 1 second. This ensured that the silhouette pattern would initially win the competition for awareness.

Six practice trials followed the instructions. On these trials, participants distinguished the location of words and non words paired with control silhouettes only. They received no feedback as to the accuracy of their decision. An experimenter stayed in the room during the instruction and practice trials to answer questions. Data from the practice trials were not taken into consideration.

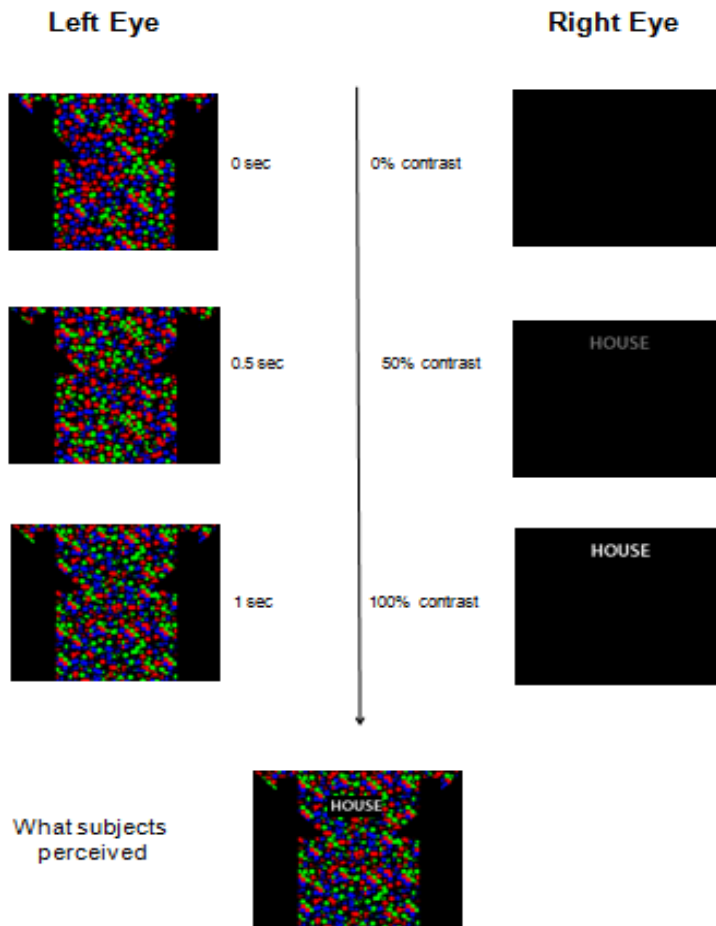


Figure 2. This is a schematic representation of the experimental word condition. In one eye, the word gradually increased from 0 to 100% within a period of 1 second. In the contrasting eye, the pattern remained dynamic throughout the entire trial. The participants viewed the stimulus binocularly and had up to 2 seconds make a top/bottom decision as soon as they perceived the letter string.

Subjects were left to complete 52 trials (13 control silhouettes paired with a word, 13 control silhouettes paired with a non-word, 13 experimental silhouettes paired with a word, and 13 experimental silhouettes paired with a non-word). Following the experimental trials, participants were asked a series of post-experiment questions to assess if they had seen any of the shapes suggested on the outside of the experimental stimuli. The data from subjects who saw shapes suggested on the ground side of the silhouettes were not analyzed. This is because our

design assumed that subjects were not aware of the hidden shapes. Only two subjects were labeled “seers” by this method; their data were not analyzed.

Following the experiment subjects were also asked, in order, if they had any impressions about the experiment, how easy was it to determine the location of the word, if they ever felt like they were guessing and if they had any strategy they used while making their decision. The participants responded on if they seen any hidden shapes, the words and non-words they remembered from the experiment. They also informed us if they had consumed any caffeine, other medications, and their dominant eye. We were interested on the potential affects these might have on the experiment.

Results and Discussion

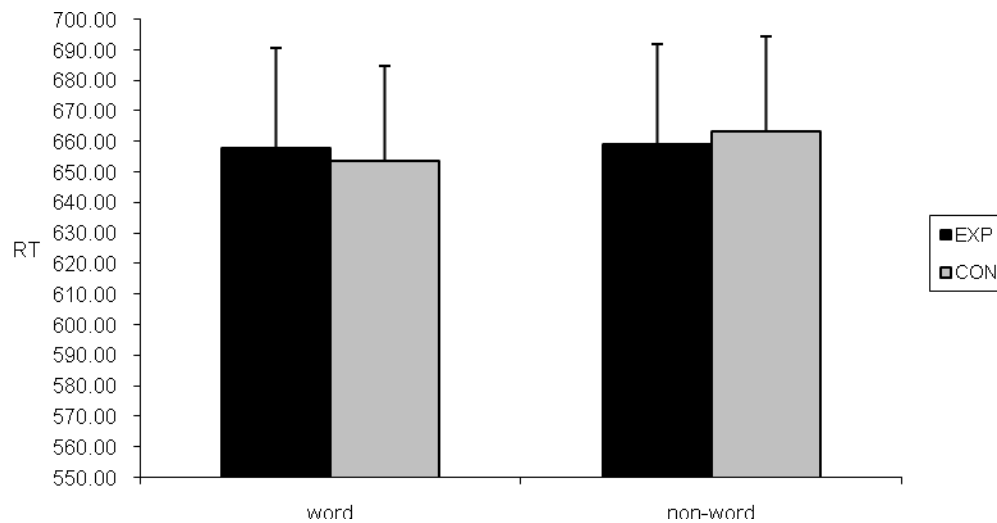


Figure 3. Reaction times for lexical detection task with experimental and control silhouettes.

Figure 3 graphs the mean RTs for each trial type. ANOVA performed on RTs with the factors of display type (Experimental versus control) and letter string type (word vs. non-word) was non-significant, $F(3, 96) = 0.198$, $p > 0.898$. There was no statistically significant difference in the RTs on experimental and control word trials, $F(1, 32) = 0.1117$, $p > 0.734$. In general, there was no evidence of facilitation or suppression in any condition of this experiment.

Discussion

Jiang et al. (2007) showed that the duration of suppression in binocular rivalry is decreased when the stimulus is either high-level form information such as a face orientation or a familiar language. Our results indicate that this finding does not extend to words versus non-words in a familiar language. It is apparent from the present study, that words do not emerge from suppression any faster than non-words. One likely reason for this is that the non-words used in this experiment were very similar in structure to the real words, (i.e. all the non-words used had the same vowel location as the real words and were easily pronounceable). Regardless, we found no evidence that high-level semantic information, available for words, facilitates the emergence of a word into awareness.

Peterson and Skow's (2008) results led to notion that the familiar configuration on the outside of the experimental silhouette is inhibited when it loses the competition for figural status. To what level this inhibition extends, (i.e. the semantic meaning of the word or just the suggested shape), is currently unknown. We had hoped that the present experiment would answer this question by showing interactions between the suppressed shape on the outside of the silhouette and the suppressed word in the non-dominant eye. Interactions between words and pictures are mediated by semantics. Thus, any evidence of an interaction would have provided evidence that

one or both of these stimuli were processed at the semantic level. That we found no interaction does not mean they are not processed semantically. Our paradigm may not be sensitive enough to reveal effects of semantic processing. Since subjects made a judgment based solely on where they saw the word emerging, whether it completely entered awareness or only partially entered awareness, it may be that complete awareness is essential to access the semantic meaning underlying a word. We tested this idea in Experiment 2 by having participants make a lexical decision rather than a location judgment, to ensure the word comes into full awareness.

Experiment 2

Everything in this experiment was the same as Experiment 1, except instead of reporting location, the subjects made a lexical decision. This was done because it would force the participant to more fully view the word and non-word before making a decision. By reading the word or non-word, we are hopeful that this will in turn allow the participant to access the semantic content, or lack thereof, which may allow us to observe whether the semantics were inhibited or facilitated.

Methods

Participants. Participants were 59 undergraduate students (21 females) from the University of Arizona subject pool. All participants had normal or corrected-to-normal visual acuity. Data from 28 participants were not analyzed because their error rate exceeded the criterion (>15%) or they saw the hidden figures in the background (2 participants).

Stimuli, Apparatus, and Procedure. The setup for this experiment was identical to the first experiment except for two key differences. First, instead of making a location decision, subjects

had to make a lexical decision (i.e., a word/non-word decision). Second, stimuli appeared on the screen for 2 seconds instead of 1 second. The letter string gradually increased in contrast for 1 second and stayed in full contrast for the remaining second. The participants still had 2 seconds to make their response.

Results

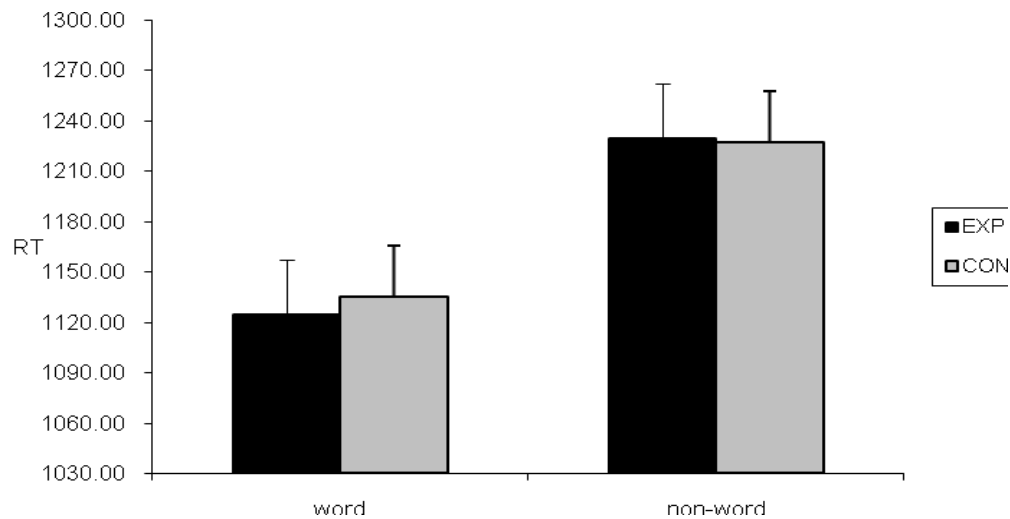


Figure 4. Reaction times for lexical decision task with experimental and control silhouettes.

Figure 4 graphs the mean RTs for each trial type. ANOVA performed on RTs with the factors of display type (Experimental versus control) and letter string type (word vs.non-word) was significant, $F(3, 90) = 24.56$, $p > 0.0001$. This was due to the significant difference between the RTs on word and non-word trials, $F(1, 61) = 68.49$, $p > .0001$. There was no statistically significant difference in the RTs between experimental and control silhouette trials, $F(1, 61) = 0.141$, $p >$

0.708, and in particular in between experimental and control word trials $F(1, 30) = 0.468$, $p > 0.499$. In general, there was no evidence of facilitation or suppression in between the conditions of interest in this experiment, rather the decision of identifying a word as it reached awareness was faster than indentifying a non-word.

Discussion

Although a decision to determine a word was faster compared to a non-word, our silhouettes had no impact on this decision. A major concern that may have affected the results was that 47% of participants exceeded our error criterion. The reason for this is that many subjects were not able to make a response within 2 seconds. This in turn may have skewed the data because their responses over 2 seconds may have yielded a significant difference between the experimental and control silhouettes in the word condition. It is also unclear whether our assumption that making a lexical decision would force participants to fully process semantic content is correct. That we found no interaction does not mean they are not processed semantically. Our paradigm still may not be sensitive enough to reveal effects of semantic processing.

General Discussion

The results in this experiment show no evidence in favor of the hypothesis that, during binocular rivalry, a shape suppressed by figure-ground competition in the dominant eye interacts with the word suppressed by binocular rivalry in the non-dominant eye. Furthermore, we found no evidence that words emerge from suppression in binocular rivalry faster than non-words. We did find faster RT's for words than non-words in the lexical decision task of Experiment 2, but

this difference may reflect decision processes after the letter string emerged into awareness. (Non-word decisions typically take longer than word decisions.)

The silhouettes used in this experiment were identical to the ones used by Peterson and Skow (2008), except in this experiment, the inside of the figure was filled with a dynamic pattern. What is unknown is whether this dynamic pattern hindered the strength of the experimental stimuli in regards to the semantic suppression entailed. Since the inside of the silhouettes were bright, colorful, and moving, the overall attention could have been so focused on the figure that the hidden familiar configurations on the outside of the silhouettes may have never been perceived unconsciously. This in turn would explain why there was no evidence of suppression or facilitation of the word. Furthermore, while the pattern was changing, the resulting edge of the figure and ground was affected in return. Since beneath the pattern was a black figure, the edge of the silhouette consistently had black dots appearing next to the background (Refer to figure 5). In the case of the experimental stimuli, this may have washed out the hidden shape and caused the null results obtained in this experiment.

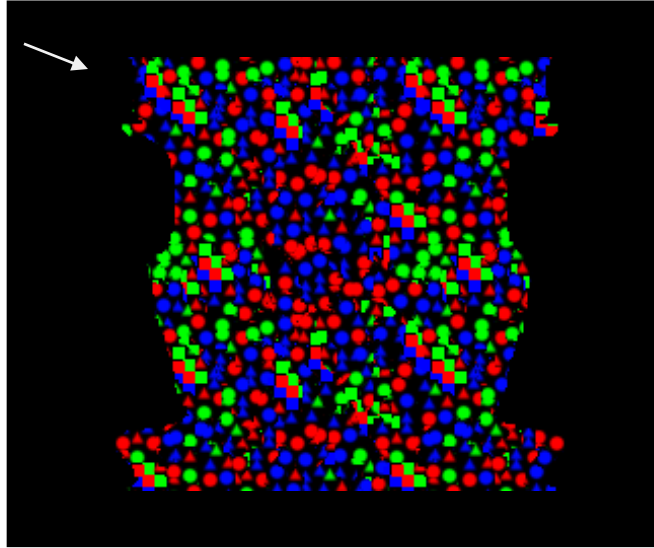


Figure 5 In this experimental silhouette, a girl is the hidden shape on the outside. If you notice where the arrow is pointing, there are black dots that appear to wash out the girl's hair when compared to the girl on the opposite side.

Another reason we may have found null results is due to the lexical tasks we had participants perform. The main concern is that the same semantic memory system may not have been accessed that the hidden configuration presumably triggers. Nelson et al. (1977) proposed that words may activate phonemic features before they activate meaningful features and pictures must always activate meaningful features before they activate phonemic features. It may be the case that the two lexical tasks performed in this experiment only accessed the phonemic features of the word rather than the semantic meaning. This would intuitively make sense assuming that semantic meaning is not required to read a word.

Another paradigm that can be employed in a follow up experiment is to have subjects make a categorical judgment about the words only. Cross modal facilitation, (pictures to words) has been demonstrated when subjects are required to make a categorical judgment (natural vs. artificial) instead of a naming task (saying the name of the word or picture). Durso & Johnson (1979) demonstrated that a word was only primed by a picture when subjects made a categorical judgment about the picture before they made a categorical judgment about the corresponding

word. Although it is unknown if words would be primed if a hidden familiar configuration was first presented in the background, this test might come closest to accessing both the same semantic memory of the word and hidden configurations. We propose in a follow up study to remove all of the non-words and have subjects make a categorical decision of natural vs. artificial (manmade) in the word condition only. This categorical decision we believe would be the best indicator in semantic judgment of our stimuli). In theory this experiment should access the same semantic content in both the word and hidden shape therefore exploring if the hidden shape suppresses or facilitates the familiar word in binocular rivalry.

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